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AUTHOR Klass, Patricia Harrington
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ABSTRACT

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Using Microcomputer Spreadsheet Programs to Teach Statistical Concepts

Patricia Harrington Klass

Illinois State University

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Running Head: Using Microcomputer Spreadsheet Programs

SE 049 113

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Abstract

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Author Notes

I would like to thank my colleagues Ronald Halinski and Barry Ankney at Illinois State University for volunteering to use these programs with their classes. Their criticisms and suggestions, as well as the comments of students and graduate assistants, have improved these programs. This research was funded, in part, by Illinois State University's Instructional Development Grant Program.

Using Microcomputer Spreadsheet Programs to Teach Statistical Concepts

One dilemma introductory statistics instructors face is deciding how much emphasis to place on hand versus computer calculations. The instructor may choose to balance the two; use hand calculations for small problems and mainframe or microcomputer packages to solve large problems. However, both of these alternatives present problems for instruction. Hand calculations are tedious and mechanical; concern for computational accuracy interferes with understanding how certain factors affect statistics. Computer packages require knowledge of programming commands and separate raw data from results. In my experience, students in introductory statistics often feel overwhelmed either by the computations or by the programming requirements of the class. They do not necessarily develop a feel for the statistical concepts, nor do they necessarily understand how different factors affect the results (Emond, 1982). A year ago, I began to develop a program that would teach students how to calculate statistics, but free them from the computational and programming burdens so they could solve many problems to gain insight into how statistics work.

Past research has shown that simulations can illustrate abstract statistical concepts and reduce time spent calculating (Abbatt & Hartley, 1981; Pulley & Dolbear 1984; Dambolena, 1986). In one study (Stockburger, 1982), students who participated in microcomputer simulations requiring them to estimate values given raw data had significantly more correct answers than a control group on a test which required quick estimations. Moreover, the nonsignificant difference in estimating one statistic was attributed to lack of practice in the experimental group, reinforcing the need for several exposures to problems to learn new concepts.

Recently, educators have used microcomputers to present simulations and to teach statistics due to their availability, accessibility, user friendly characteristics, flexibility, versatility, and economy (Hsaio, 1985). In addition to their use in individual learning, microcomputers can be used during lectures or presentations as teaching tools to accommodate "what if" questions, which neither hand calculations nor mainframe computers can address. However, for my purposes, microcomputer statistical packages had some of the same limitations as the mainframe versions.

I decided to use a spreadsheet program because it could link the data to the results, it is easy to program, and it provides graphs. Through the use of "macros," I designed the templates so students would enter only numbers, value labels, and single-letter commands. Several articles have published sample spreadsheet templates that teach concepts such as the normal curve (McKallip, 1987), *t* tests (Clausen, 1988), linear equations (Criddle, 1987) and multiple regression (Hsaio, 1985). Furthermore, "a major advantage of performing calculations using a spreadsheet is that multiple cases can be examined, giving the student a feel for the sensitivity of the results to changes of input data" (Nash & England, 1986, p. 91). The spreadsheet templates were designed to meet three objectives: aid instruction through numeric and graphic presentations, guide students with structured activities stressing basic concepts, and emphasize

discovery learning via supplemental instruction. Charney and Reder (1986) found that programs which used a mix of guided practice and problem solving (discovery learning) produced significantly higher test results than guided practice alone.

A CAI development and testing model described by Mausner, et al. (1983) was used: the templates and guided activities capitalized on the unique interactive capabilities of the computer and the simplicity of the spreadsheet programs, teachers and tutors who used the programs attended a training session, and a formative evaluation measured whether the materials matched the needs of the students and blended into the existing curriculum. Two introductory research methods and statistics classes used and evaluated the microcomputer spreadsheet templates during the summer of 1987. One section of the introductory research methods and statistics class will evaluate the revised templates and workbook spring 1988.

Materials

I used the VP-Planner spreadsheet program to write the templates due to the software's availability, cost, and simplicity; however, any spreadsheet program would work. Twelve templates were developed: descriptive statistics, the normal curve and standard scores, independent and dependent t tests, Pearson correlation, 2X2 and 2X3 chi square, three- and four-group one-way analysis of variance (ANOVA), two-way ANOVA, and simple and multiple regression. As students manipulate data, they see the statistics change. The results appear with the raw data and formulas. Students can calculate, print, and graph without learning to program. The printouts provide the results and lead students through the hypothesis-testing steps.

The following guidelines influenced the design of the templates and workbook:

1. The purpose was to emphasize statistical concepts over computation.
2. The templates would supplement and enhance classroom instruction, not replace it.
3. Data entry and commands would be simple. I assumed students had no prior experience with microcomputers.
4. The workbook would lead students through the structured exercises, which emphasize underlying concepts.
5. All templates would provide graphs.
6. All information (raw data and results) would appear on one screen simultaneously.
7. Students would solve many problem sets in a class session.
8. Students would work in pairs in lab sessions so they could discuss questions and participate actively.
9. A follow-up assignment using real data would supplement the workbook examples.

Sample Template

The 12 templates and workbook chapters have the same format. For that reason, a detailed description of one template, three-group one-way analysis of variance, follows. As seen in Figure 1, students learn nine, one-letter mnemonic commands; ALT P prints results, ALT C calculates, ALT G graphs results, and ALT Q quits from VP-Planner.

Insert Figure 1 about here

From the main menu, students would select ALT H to view the three-group one-way ANOVA example. The workbook assignment for each lesson presents an overview of the statistic and its use, the objectives or underlying concepts to be learned, the name of the program, an eight-step list of instructions, and the context of the problem (See Appendix). Once the student accesses the program, the data screen appears as displayed in Figure 2. On the left-hand side, students enter the labels and raw scores for each group. This template allows students to enter up to 20 cases per group although the workbook problems are limited to 5 or 6 cases per group. (The number of cases varies by program; the dependent t-test, Pearson correlation, and regression problems allow for 25 cases, while the four-group ANOVA allows for 80. The single-page guideline limits how many data points can be entered.)

Insert Figure 2 about here

On the right-hand side, the ANOVA summary table results appear on top, followed by the descriptive statistics for each group, the pairwise comparisons, and the t and q statistics. The t formula used is: M1 - M2 /$\sqrt{}$(msw * (1/n1 +1/n2)). The q formula is M1 - M2 / $\sqrt{}$(msw/n); therefore, this statistic requires equal number of cases in each group. The basic computations for these calculations are hidden in another part of the template, now shown at the bottom of Figure 2.

For each result, students view a graph which reinforces how the statistic is computed. As seen in Figure 3, the one-way ANOVA graph displays the mean square between groups, the mean square within groups, and the F ratio. In other templates the t test displays the differences in means, the standard error, and the t ratio while the regression problems displays a pie chart with the percent of explained to total variation.

Insert Figure 3 about here

Each workbook chapter treats from three to five concepts. The one-way ANOVA exercises show how three factors affect the results: differences between groups, differences within groups, and changes in sample size. At the end of each chapter, an optional exercise provides additional problems or suggestions for individual exploration.

After students finish the exercises, they discuss the results in class and complete a follow-up assignment with a real data set. This semester, a memory experiment replicating one by Ornstein, Trabasso, and Johnson-Laird (1974) serves as the data set. As students learn the statistics, they test hypotheses for the variables collected in

class. As seen in Table 1, the class can learn several different statistics with the data set. This semester, the class has used the data to learn descriptive statistics, correlations, and independent and dependent t tests.

Insert Table 1 about here

Students may print out any problem they wish. As seen in Figure 4, the one-page printouts contain the raw data, the results, and a series of questions related to hypothesis testing. The hypothesis-testing questions do not appear in the workbook, which concentrates solely on what affects the statistic. I have asked students to complete the printouts as homework assignments and as test questions.

Insert Figure 4 about here

Results

As seen in Table 2, students viewed the programs positively; 93.5% of the students agreed that the exercises aided their understanding of the course material (M=4.20), while 73.9% agreed that they felt more comfortable using the microcomputer after taking the course than when they began (M=3.85). The students who had the least experience agreed more strongly that their comfort increased; 100% of those who had no or very little experience agreed that they felt more comfortable using microcomputers. Over 82% disagreed that the exercises were too difficult (M=1.94). The ratings for the graphs (M=3.67), printouts (n=27; M=3.76), and clarity of instructions (M=3.37) were less positive than the other components.

Insert Table 2 about here

Discussion

The students' responses to the statistics spreadsheet programs were positive. Most students agreed that they felt more comfortable using computers, the programs aided their understanding of the course material, and the assignments were not too difficult. These results are similar to responses for an Apple program tested by Schafer and Johnson (1985) where 84% of the students thought the computer assignments were appropriate for the course and 93% thought the package was relatively easy to use. The templates and workbook were modified during the fall 1987 semester based on the evaluations and comments offered by students and instructors. The comments centered on six areas, and the changes address each of these.

First, the templates were too automated; students had little control over the cursor's movement. Students "crashed" or "froze" the programs through typing errors or through overriding the automated

commands. Some of the automation has been removed to prevent these major errors. Second, students asked for more explicit directions. Although discovery learning was a goal, students needed more guidance. Now the workbook explains what to look for as each concept is introduced. Third, students asked for a written overview of the statistic used in each exercise. Now the workbook gives a short introduction about the statistic and tells how it is used in research.

Fourth, many students thought the graphs were difficult to interpret and did not see their connection with the numeric presentations. The graphs now display the key parts of the formulas for each statistic. For example, the original ANOVA graph gave the means and the standard deviations for the three groups. The students did not see how this graph related to the results, so the graph now displays the mean square between, the mean square within, and the F ratio. Fifth, many of the workbook exercises originally asked questions about hypothesis testing and calculations. Students thought that presenting both was too much. Therefore, the workbook activities now are limited to the factors affecting the statistics. At the computer, students can concentrate on the statistics, but when they obtain printouts, they practice the hypothesis-testing steps on their own. Last, students wanted the workbook's layout and instructions to correspond more directly to the screen's format, and these changes now appear.

In addition to the limits mentioned above, the major constraint of the templates is the one-page guideline. This limit was deliberate. The goal of the spreadsheet program is to emphasize the close ties between the data and the results not to replicate statistical packages. Currently, one can enter from 25 to 80 cases; however, if I created a separate data entry grid this could increase. Students would first enter the data, then calculate and view the results by using a one-letter command (ALT R) much like they do now to view the graphs. This modification may not be worth the effort; with large data sets, students would have to enter all the numbers each time they used a different template. Furthermore, a data set like the one in Table 1 cannot be entered and saved in one part and then read later by different templates. Unlike statistical packages, the templates are not generalizable to other problems; a separate template is needed to go from a three-group to a four-group ANOVA. Unbalanced ANOVA, 2x3, 3x3 and 3x4 ANOVA's are common examples; each of these templates needs to be created. Another goal is to display sampling distributions for each statistic so a class can see how sample size and standard errors affect the distributions. The normal curve template could be changed easily to a sampling distribution of the mean. The t, F and chi-square distributions will be more difficult because they all require a gamma function in their formulas, and the version of VP-Planner used in these templates has no calculus functions.

In summary, this is an on-going project. The goal is to produce a viable teaching and learning alternative to hand calculations and statistical packages. Preliminary results show that these templates can be used in class instruction and in lab sessions. By using these templates, students can reduce the time needed for computations and increase the time spent learning statistical concepts.

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Figure 1. VP-Planner Flow Chart and Commands

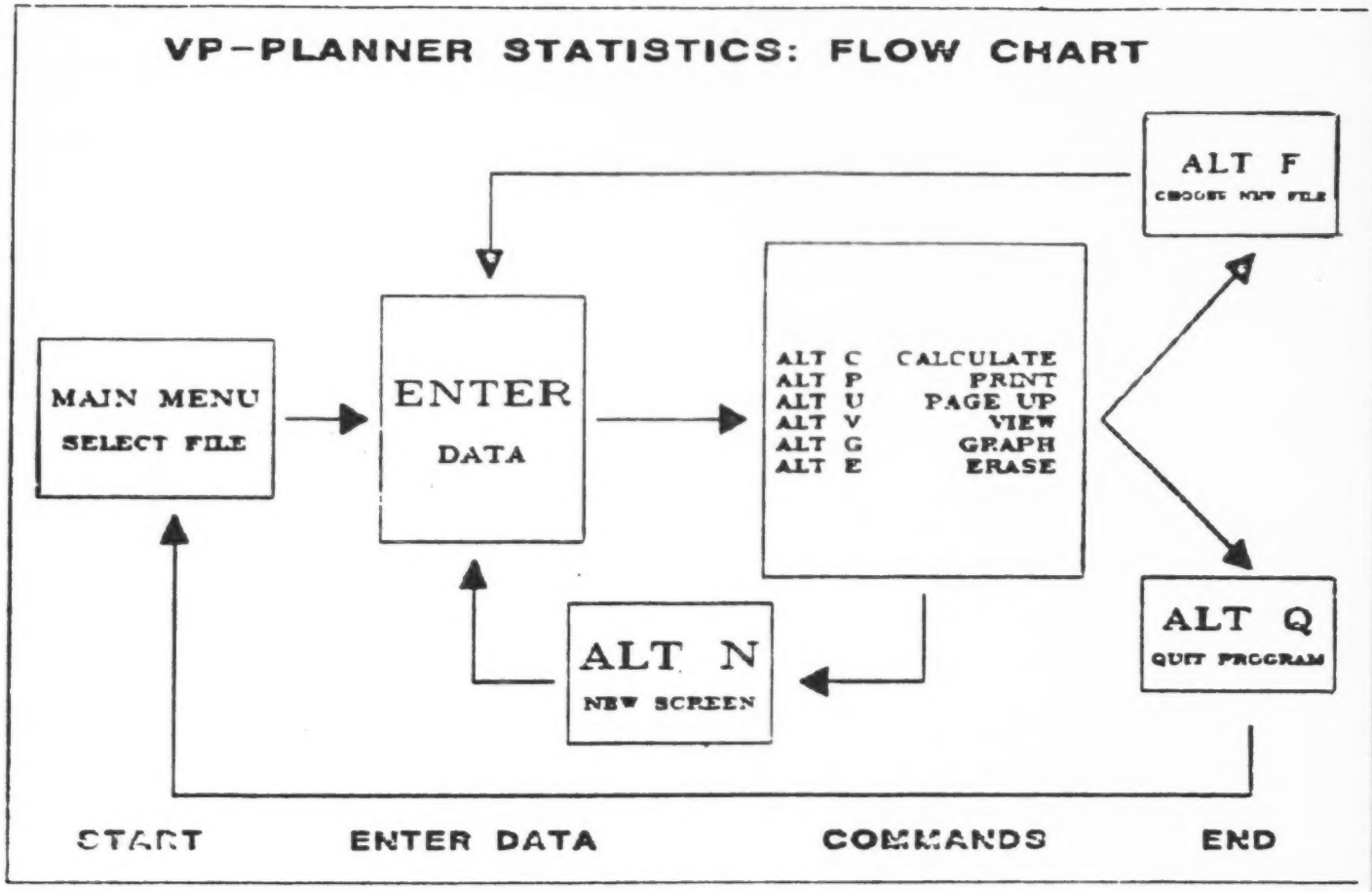


Figure 2. Analysis of Variance Template

.IND		ANALYSIS OF VARIANCE			DEP				
VAR=	EXERCISE GROUP				VAR =	ENDURANCE			
	ENTER 3 GROUP NAMES BELOW					ANOVA SUMMARY TABLE			
	NO	LOW	HIGH		SOURCES	s	df	ms	F
#1	1.00	6.00	11.00		Between	250.00	2	125.00	50.000
#2	2.00	7.00	12.00		Within	30.00	12	2.50	
#3	3.00	8.00	13.00		TOTAL	280.00			
#4	4.00	9.00	14.00				GROUP1	GROUP2	GROUP3
#5	5.00	10.00	15.00		n	=	5	5	5
#6					MEAN	=	3.00	8.00	13.00
#7					SD	=	1.58	1.58	1.58
#8									
#9							PAIRWISE COMPARISONS		
#10							1 V 2	1 v 3	2 v 3
#11					MEAN DIFF =		-5.00	-10.00	-5.00
#12					t =		-5.00	-10.00	-5.00
#13					q* =		-7.07	-14.14	-7.07
#14					* = n only				
#15									
#16					COMPARE VALUES ABOVE TO t OR q TABLE				
#17									
#18									
#19									
#20									

		GROUP1	GROUP2	GROUP3	
n	=	5	5	5	
Σ	=	15	40	65	
MEAN	=	3.00	8.00	13.00	
SD	=	1.58	1.58	1.58	
VAR	=	2.50	2.50	2.50	
Σ SQ	=	10.00	10.00	10.00	
					$\Sigma Tj^2/n$
Tj^2/n		45	320	845	1210
$\Sigma\Sigma X^2$		55	330	855	1240
T^2/N					960
T		120			
sst=		280			
ssb=		250			
ssw=		30			

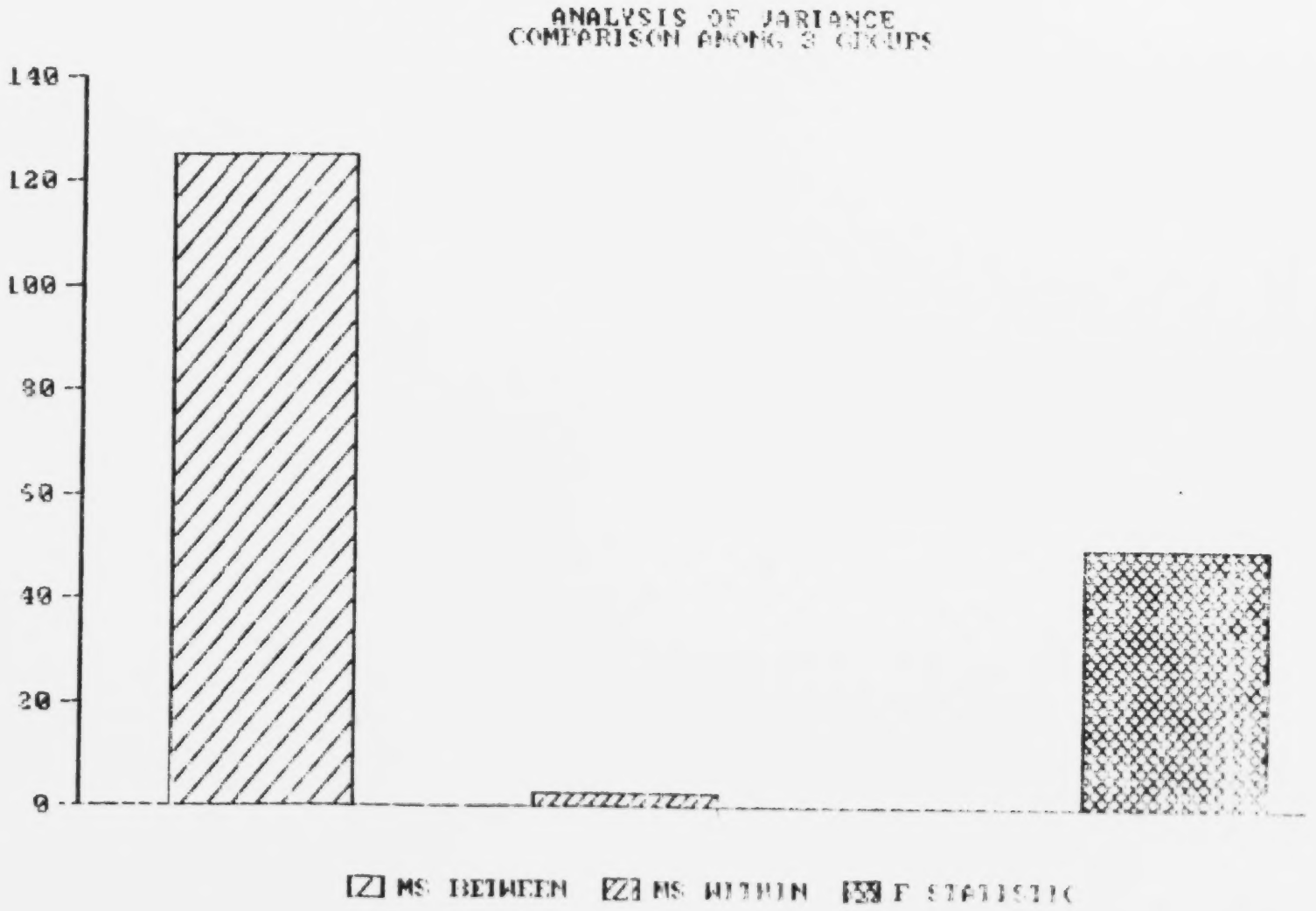


Figure 3. Analysis of Variance Graph

Table 1

Memory Experiment Data Base

ID	Group	Age	Sex	GPA	Status	Alert	Anxiety	Cat.	Noncat.	Total	Major
1	1	43	2	3.20	2	3	3	8	1	9	5
2	1	48	2	3.70	2	4	2	13	4	17	4
3	1	37	1	3.39	1	3	3	11	4	15	1
4	1	35	2	3.80	2	3	1	15	4	19	5
5	1	33	2	3.50	1	4	5	14	7	21	5
6	1	39	1	3.60	1	2	2	9	0	9	4
7	1	38	2	3.00	2	4	4	11	9	20	6
8	1	27	2	3.86	1	5	3	15	7	22	3
9	1	47	2	3.00	2	4	3	13	2	15	6
10	1	27	2	3.50	2	3	3	14	4	18	2
11	1	23	2	3.00	1	4	3	11	4	15	1
12	2	35	2	3.60	2	4	4	8	5	13	3
13	2	39	2	3.98	2	3	5	10	2	12	4
14	2	28	2	3.80	1	5	2	2	1	3	6
15	2	23	2	3.75	1	4	3	17	6	23	4
16	2	29	2	3.80	1	4	2	16	4	20	1
17	2	44	2	2.98	1	4	2	13	4	17	6
18	2	42	2	4.00	2	4	3	12	3	15	5
19	2	22	2	2.30	1	4	3	15	5	20	2
20	2	29	1	3.00	1	4	4	11	5	16	6
21	2	24	2	3.80	1	3	2	11	3	14	2
22	2	28	1	2.20	1	3	2	6	1	7	6
23	2	35	2	3.00	1	3	3	18	2	20	1

Group 1=intentional
2=incidental

Sex 1=male
2=female

Major 1=SED 2=Counselor Ed. 3=EAF 4=C&I 5=Reading 6=Outside Ed.

Status 1=full-time 2=part-time

Alertness, Anxiety 1=none 2=little 3=moderate 4=high 5=very high

Figure 4. Analysis of Variance Printout

IND VAR= EXERCISE GROUP — ANALYSIS OF VARIANCE — DEP VAR = ENDURANCE

ENTER 3 GROUP NAMES BELOW	NO	LOW	HIGH
#1	1.00	6.00	11.00
#2	2.00	7.00	12.00
#3	3.00	8.00	13.00
#4	4.00	9.00	14.00
#5	5.00	10.00	15.00
#6			
#7			
#8			
#9			
#10			
#11			
#12			
#13			
#14			
#15			
#16			
#17			
#18			
#19			
#20			

ANOVA SUMMARY TABLE

SOURCES	s	df	ms	F
Between	250.00	2	125.00	50.000
Within	30.00	12	2.50	
TOTAL	280.00			

	GROUP1	GROUP2	GROUP3
n =	5	5	5
MEAN =	3.00	8.00	13.00
SD =	1.58	1.58	1.58

PAIRWISE COMPARISONS

	1 V 2	1 v 3	2 v 3
MEAN DIFF =	-5.00	-10.00	-5.00
t =	-5.00	-10.00	-5.00
q* =	-7.07	-14.14	-7.07

* = n only

COMPARE VALUES ABOVE TO t OR q TABLE

1. Write the formula for the F statistic.
   F=

2. Insert the values from the summary table into the formula & solve.

   F=

3. State the research and the null hypotheses.

4. Use the F table; what is the critical value needed to reject the null at the .05 significance level?

5. Compare the calculated F to the critical value.
   Do you accept or reject the null hypothesis? _____ Why?

6. If the F is significant, calculate Fisher's LSD (protected t) and Tukey's HSD as follow-up tests. According to these two criteria, which pairs differ significantly?
   (Use the t and q statistics reported above.)

7. Summarize the results.

Table 2

Mean Student Evaluation Scores of Spreadsheet Program

	n	M[a]	SD
The computer workbook exercises aided my understanding of the course material.	46	4.20	.54
The computer graphics aided my understanding of the course material.	46	3.67	1.55
The printout assignments aided my my understanding of the course material	37	3.76	.86
I am more comfortable using the microcomputer now than I was before taking this course.	46	3.85	.91
The exercises were too difficult.	46	1.94	.65
The instruction booklet was clearly written.	46	3.37	1.04

[a] 1= Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree

Appendix

One-way Analysis of Variance Workbook Exercises

ONE-WAY ANALYSIS OF VARIANCE

INTRODUCTION: The one-way analysis of variance is used when the researcher wants to compare the means of two or more groups. The F ratio shows the amount of variation due to differences between groups divided by the amount of variation due to differences within groups (error). If there is no difference between the groups, F is approximately 1. The F statistic can range from 0 to some infinitely large positive number. F increases when the difference between the groups is greater than the differences within each group. The F statistic is affected by various factors. This exercise will help you explore some of those factors.

OBJECTIVE: To gain an understanding of how the F statistic in the analysis of variance is affected by:

1) differences between groups
2) differences within groups
3) differences in sample sizes

PROGRAM: To access the ANOVA(1X3) program from the main menu, press ALT H.

INSTRUCTIONS:

1) Enter the value labels and the data;
2) Calculate the results (ALT C);*
3) Record the results in the workbook;
4) View the graph (ALT V);
5) Plot the graph in the workbook;
6) Return to the data screen (↵);
7) Clear data screen for NEW problem (ALT N);
8) Repeat steps 1 to 7.

CONTEXT:

Three "equal" groups of students were used in an experiment to test the effectiveness of low impact aerobics versus high impact aerobics versus no exercise (control group). Endurance tests were given after a nine-week session; endurance was measured by recording the number of full minutes of strenuous exercise. The independent variable is EXERCISE GROUP; the three exercise categories are No, Low Impact, and High Impact aerobics classes. The dependent variable is ENDURANCE.

I. The following five examples demonstrate how the F statistic is affected by changes in the differences of the group means when within group differences remain constant.

*

NOTE: The calculated q statistic is valid only when there are equal n's in each group.

1) ENTER the following LABELS and NUMBERS:

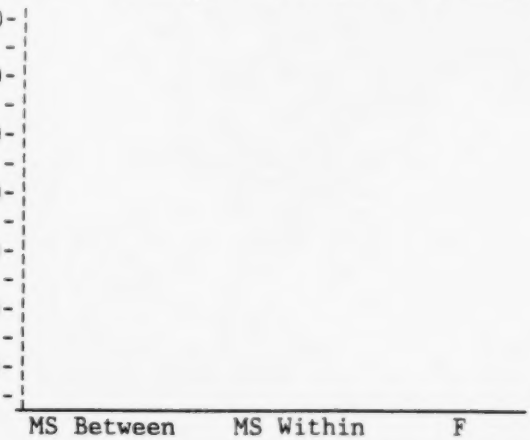
NO	LOW	HIGH
1	6	11
2	7	12
3	8	13
4	9	14
5	10	15

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).



2. ENTER the following LABELS and NUMBERS:

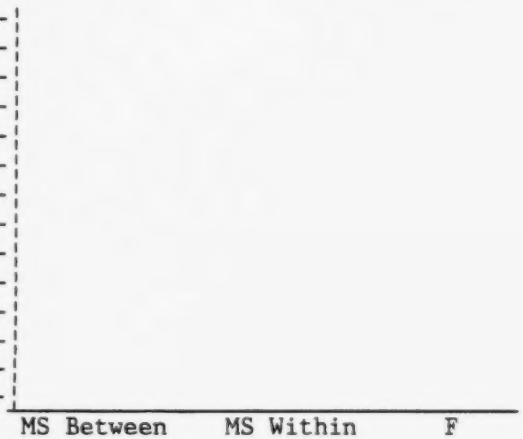
NO	LOW	HIGH
1	10	16
2	11	17
3	12	18
4	13	19
5	14	20

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).



3. ENTER the following LABELS and NUMBERS:

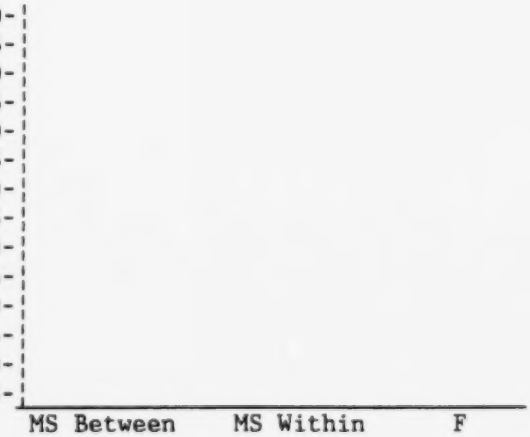
NO	LOW	HIGH
6	6	11
7	7	12
8	8	13
9	9	14
10	10	15

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).



4. ENTER the following LABELS and NUMBERS:

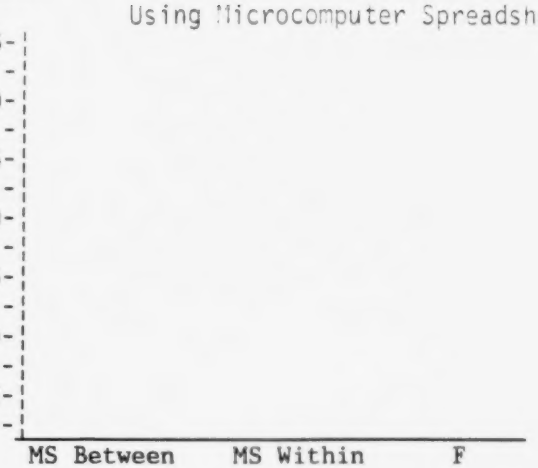
NO	LOW	HIGH
6	6	7
7	7	8
8	8	9
9	9	10
10	10	11

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).



5. ENTER the following LABELS and NUMBERS:

NO	LOW	HIGH
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).

c) Describe the effect of changing the differences in group means on the F statistic while keeping differences within groups constant.

d) What does a large F imply?

e) What does a small F imply?

II. The following five examples demonstrate how the F statistic is affected by changes in the differences within groups while the differences between groups remain constant.

1) ENTER the following LABELS and NUMBERS:

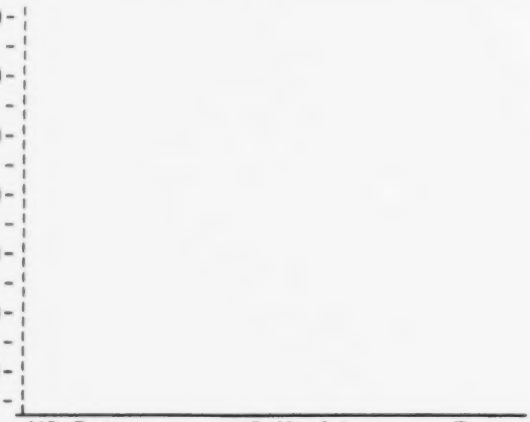
NO	LOW	HIGH
6	11	16
4	9	14
6	11	16
4	9	14
5	10	15

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).



2. ENTER the following LABELS and NUMBERS:

NO	LOW	HIGH
7	12	17
3	8	13
8	13	18
2	7	12
5	10	15

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).

3. ENTER the following LABELS and NUMBERS:

NO	LOW	HIGH
8	13	18
2	7	12
9	14	19
1	6	11
5	10	15

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).

4. ENTER the following LABELS and NUMBERS:

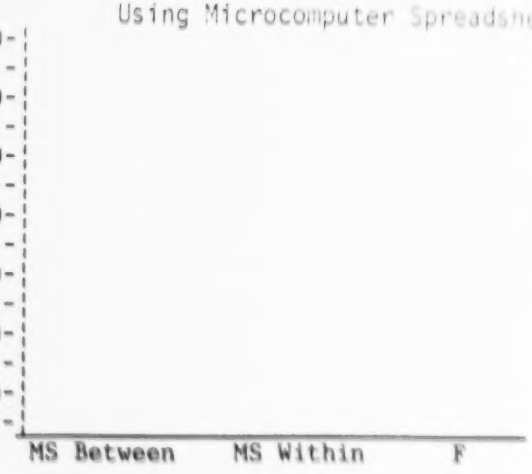
NO	LOW	HIGH
8	2	15
1	18	20
6	6	10
10	14	8
0	10	22

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).



5. ENTER the following LABELS and NUMBERS:

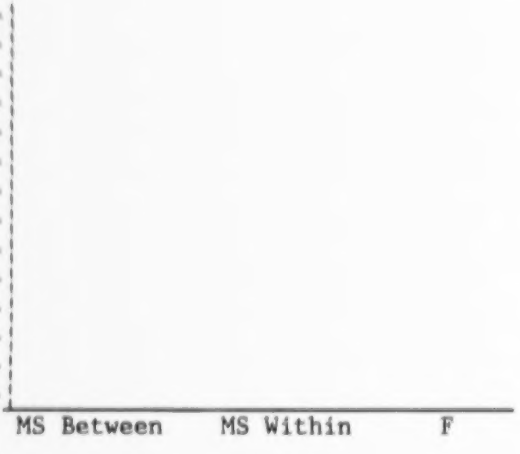
NO	LOW	HIGH
1	26	30
0	4	15
0	16	16
0	4	14
24	0	0

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).



c) Describe the effect of changing the variability within groups on the F statistic while keeping group means constant.

d) What does a large F imply?

e) What does a small F imply?

III. The following three examples demonstrate how the F statistic is affected by changes in sample size when the differences in means and the variability within groups remain constant.

1. ENTER the following LABELS and NUMBERS:

NO	LOW	HIGH
8	2	15
1	18	20
6	6	10
10	14	8
0	10	22

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).

2. ENTER the following LABELS and NUMBERS (Double the number of cases):

NO	LOW	HIGH
8	2	15
1	18	20
6	6	10
10	14	8
0	10	22
8	2	15
1	18	20
6	6	10
10	14	8
0	10	22

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).

3. ENTER the following LABELS and NUMBERS (Add 5 more cases):

NO	LOW	HIGH
8	2	15
1	18	20
6	6	10
10	14	8
0	10	22
8	2	15
1	18	20
6	6	10
10	14	8
0	10	22
8	2	15
1	18	20
6	6	10
10	14	8
0	2	22

a) Calculate the results (ALT C).

	NO	LOW	HIGH
MEAN=	_____	_____	_____
SD =	_____	_____	_____

MS Between = _____
MS Within = _____
F= _____ df= __,___

b) View and plot the graph (ALT V).

c) Describe the effect of changing the sample size on the F statistic while keeping the means and variability constant.

d) What does a large F imply?

e) What does a small F imply?

IV. OPTIONAL EXERCISE.

1. Compare the observed F results above to the tabled F values in your text for an alpha level of .05. Note which results are significant.

2. Re-enter the numbers in the problems above when the F statistic is significant in order to conduct post-hoc comparisons.

3. For each pairwise comparison, find and record the t and q statistics that appear on the monitor.

4. Compare the results to the tabled t and q values (r = 3) in your text.

5. Summarize your results and record which pairs differ significantly according to Fisher's protected t and Tukey's HSD criteria.